exploring gas laws

instructional computing courseware
for the **apple® II** computer

This manual is compatible

with

the ***Exploring Gas Laws*** disk

Version 1.0

MECC warrants that it will, at its option, repair, replace, or return the purchase price of any product found by MECC to be defective in quality or for any other reason, and which is returned to MECC, postage paid. This warranty replaces and supersedes all other warranties stated or implied, including any warranty of design, merchantability, or fitness for a particular purpose or use. MECC will not be liable for any incidental, special, or consequential damages resulting from any use of or defects in the product.

© MECC
3490 Lexington Avenue North
St. Paul, MN 55126

ISBN 0-87490-713-6

June 1989

Copyright ©1989 by MECC. All rights reserved. This software and manual may not be copied or transferred to another medium except as permitted by U.S. Copyright Law or as authorized by written agreement with MECC. Apple® and ProDOS® are registered trademarks of Apple Computer, Inc., of Cupertino, California.

Library of Congress Cataloging-in-Publication Data

Exploring gas laws [computer file]. —Version 1.0.

1 computer disk : col.; 5 1/4 in. + 1 manual.
System requirements: Apple II series; 128K; ProDOS; BASIC; 1 disk drive; monochrome or color monitor; Apple-compatible printer optional.
Title from title screen.
Edition statement from disk label.
Copy-protected.
Audience: Children (grades 11-12)
Issued also on 3 1/2 in. computer disk.
Summary: An easy-to-use discovery-learning simulation of the behavior of an ideal gas under conditions determined by secondary chemistry and physics teachers or learners. It is expected that students will use this program as a resource to discover or review the behavior of gases as described by the Ideal Gas Law, Charles' Law, Boyle's Law, or Gay-Lussac's Law.
"A-229"— Disk label.
1. Ideal gas law—Software. [1. Ideal gas law—Software. 2. Gases—Software] I. Minnesota Educational Computing Corporation.
QC161.2.E96 1989 536.'412'01135369 89-11253
ISBN 0-87490-713-6

TABLE OF CONTENTS

Introduction 1

Description of **Exploration Lab** 2

The Program at a Glance 3

Use in an Instructional Setting 12

Thinking Skills 16
- Using MECC Science Products to Reinforce Core Thinking Skills 16
- Thinking Skills and ***Exploring Gas Laws*** 17
- A Framework for Thinking 18

Classroom Activities 20

Informational Bulletin #1: Introducing ***Exploring Gas Laws*** Variables 24

Informational Bulletin #2: Introducing ***Exploring Gas Laws*** Support Options 25

Informational Bulletin #3: Introducing ***Exploring Gas Laws*** Action Options 26

Informational Bulletin #4: Introducing ***Exploring Gas Laws*** Reference Information 27

Exploring Gas Laws Data Collection Worksheet 28

Textbook Correlation 29

Credits 32

References 33

MECC Services 34

INTRODUCTION

Exploring Gas Laws includes a discovery-learning program called **Exploration Lab**. The goal of this program is to enable secondary chemistry, physics, and physical science students to pose "what if?" questions about the behavior of an ideal gas. Because there cannot be incorrect answers to this kind of question, the program does not need to provide remediation. Furthermore, the program is designed to be a tool that teachers will integrate into their lesson plans to demonstrate the principles involved so that their students can acquire, compare, and contrast information about the behavior of an ideal gas. They will also encourage students to predict and to demonstrate the behavior of a gas under a given set of conditions.

Exploring Gas Laws is designed to be used with classroom lessons, textbook chapters, and laboratory investigations on the topic of the behavior of gases as described by the gas laws. While the program is designed for teacher-centered demonstrations in a single-computer classroom, it is also suited for individualized student exploration.

Exploring Gas Laws enables students to gain an understanding of the gas laws by determining how each of the variables (temperature, pressure, volume, and amount) influences the behavior of an ideal gas under controlled conditions. This product enables teachers to provide students with an unguided, open-ended environment in which to study the Ideal Gas Law, Charles' Law, Boyle's Law (also attributed to Mariotte), or Gay-Lussac's Law (also attributed to Amonton).

Exploring Gas Laws provides a great deal of flexibility and user control. Most aspects of an investigation can be controlled from a single screen. Interaction options are displayed at all times and support options are menu-driven. Each of the gas laws provides at least three equation variations from which to choose. Equations can be displayed on the main screen in both static and active form. The active form of an equation constantly updates variable values as teachers or students make changes. The equations can also be removed from the display.

In addition, selected variable conditions, their units, and their effected changes are clearly displayed at all times. The program includes four variable options: temperature, pressure, volume, and amount (n). It includes three support options: charts, graphs, and equations. It also includes six action options: display, escape, increment, help, mask, and print. Program settings allow the user to select units for pressure and volume that match the textbook currently in use and to specify increments.

It is assumed that students will receive preparation before and guidance while using ***Exploring Gas Laws.*** This product is designed to emphasize and support the use of science process skills, as well as to provide a channel for learning and understanding recommended concepts and principles. The goal is that this program will either lead to or follow from student-centered laboratory investigations dealing with the gas laws. Thus, while the product is firmly grounded in recommended secondary chemistry and physics content, it also features a strong process orientation.

DESCRIPTION OF EXPLORATION LAB

Exploring Gas Laws is an easy-to-use discovery-learning simulation that demonstrates the behavior of an ideal gas under conditions determined by secondary chemistry and physics teachers and learners. This product is primarily designed be used in a demonstration mode. It is expected that teachers will use it as a resource to provide students the opportunity to discover or review the behavior of gases as described by the Ideal Gas Law, Charles' Law, Boyle's Law, or Gay-Lussac's Law.

Curriculum Area:	Chemistry, Physics, Physical Science
Subject:	The behavior of gases
Topic:	The gas laws: Ideal Gas Law, Charles' Law, Boyle's Law, and Gay-Lussac's Law
Type:	Discovery-learning simulation
Grade Range:	11-12
Operational Mode:	Large group demonstration, Individualized instruction
Hardware:	Requires an Apple II series computer with at least 128K of memory and one disk drive

When using these programs, students will be able to:

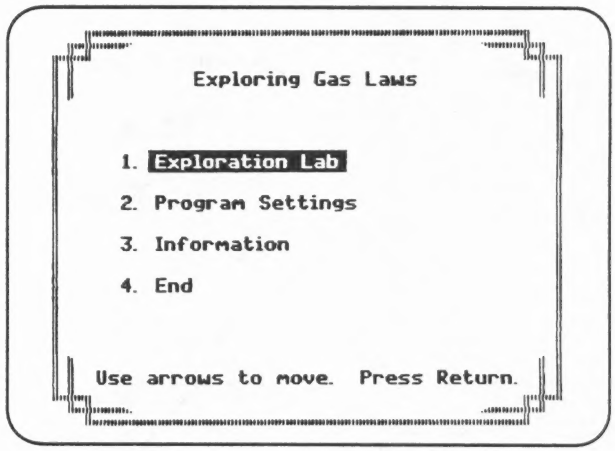
- compare and contrast information on the relationships among temperature, pressure, volume, and amount of gas in a container;
- describe how each variable changes with a change in any of the other variables;
- predict the behavior of a gas, based on selected variable settings;
- state and demonstrate each of the gas laws (Ideal Gas Law, Charles' Law, Boyle's Law, or Gay-Lussac's Law) and use them to solve problems;
- state the kinetic theory description of a gas and relate these basic assumptions to the gas laws; and
- explain why real gases behave differently from what would be expected as predicted by the gas laws.

THE PROGRAM AT A GLANCE

This section of the manual provides you with a description of each main menu option and a brief look at the gas law's simulation, variables, support options, and action options. To begin, place the disk in the disk drive and turn on the computer.

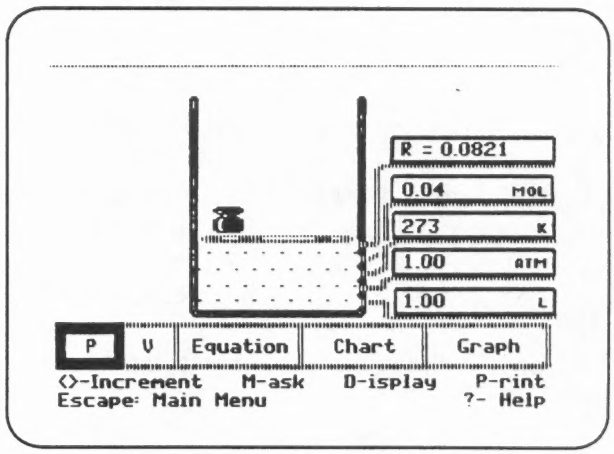
Main Menu

The main menu screen displays four options. Option 1 takes you to the gas laws simulation. Option 2 allows you to select units, specify increments, and edit printer support. Option 3 provides you with a program description and MECC product information. Option 4 ends the current session of **Exploring Gas Laws.**



Exploration Lab

Use the arrow keys to highlight Option 1, Exploration Lab, and press Return. When the Exploration Lab screen appears (shown here), you are ready to begin your investigations. This screen displays a gas-filled cylinder, data gauges, variables, support options, and action options. Your task is to discover how each of four variables influence the behavior of an ideal gas under controlled conditions.



For all but the Ideal Gas Law, an experiment is a two-step process. Begin by selecting a set of starting values. Carry out the experiment by increasing or decreasing those values using the Greater Than (>) or Lesser Than (<) Keys.

Note: All the options necessary to successfully operate the simulation appear on the bottom of the screen.

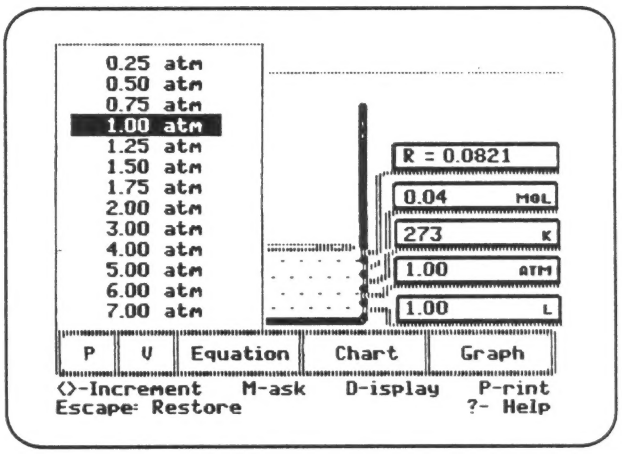
Variables and support options appear in the menu bar. Select these options with the arrow keys and press Return.

Action options appear below the menu bar. Select these options by pressing the key(s) indicated immediately to the left of the option name.

THE PROGRAM AT A GLANCE (continued)

Variable Selections

When you enter the program for the first time, two variables, pressure and volume, are displayed in the menu bar. (To select a different set of variables, see "Equation," on page 6.)

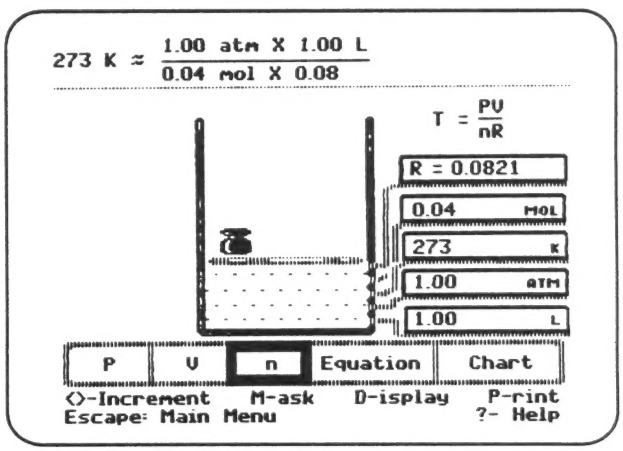


Investigating Boyle's, Charles', and Gay-Lussac's Laws is a two-step process.

1. Begin by selecting initial values of your choice for the two variables shown. There are two ways to select initial values.
   - You can choose each of the variables in turn by using the arrow keys to move the highlighted box to a variable symbol and press Return. From the window that opens, make variable condition choices in the same manner. (To leave the window without making a choice, press Escape.)
   - You can also enter a value directly from the keyboard when the highlighted box is on a variable symbol and press Return.

Note: Entered values must be larger than 0.001, smaller than 99999, or begin with a digit (as in 0.01), not a decimal point.

2. Continue the investigation by increasing or decreasing the initial values using the > and < Keys.
   - Setting a new initial value will reset other displayed values and begin a new experiment. To set a new increment size, see "Specify Increments," on page 9.

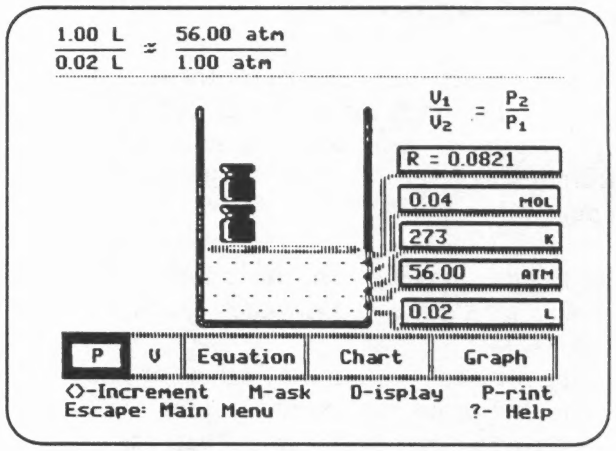


Ideal Gas Law investigations have no starting or initial value concept.

3. Carry out your experiments by selecting, entering, or increasing or decreasing values for one or more of the three variables as needed. Selecting or entering values does not restart the experiment as in the three laws described above.

THE PROGRAM AT A GLANCE (continued)

Changing a variable affects the graphic display of the gas-filled cylinder and the data displayed. Approximate changes may be observed in the position of the plunger, width of the cylinder, and number of weights. The numeric data will be displayed in the gauges and equation.



Note: Values appearing in E (scientific) notation, such as $2.7E^{-3}$, are read as 2.7×10^{-3}.

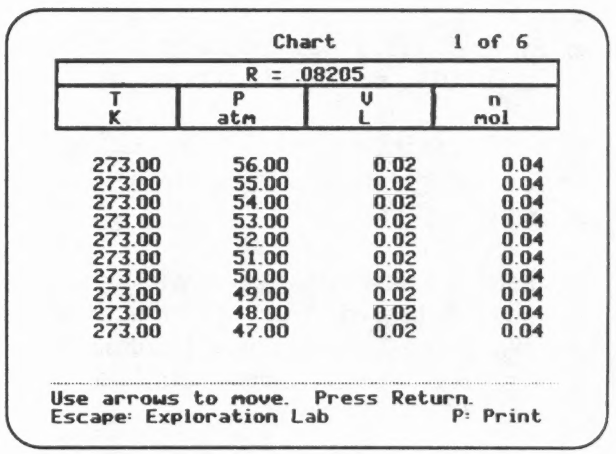
The effect that each variable has on the behavior of the gas is in turn influenced by the condition set for other variables. You can change variable conditions and observe these changes as often as you want.

Teacher Hint: Encourage students to use good scientific procedure by changing only one variable at a time. Changing more than one variable at a time makes it impossible to judge which condition modified the behavior of the gas or how much the behavior was modified.

Chart

By selecting Chart, you can view the variable conditions of each trial for the current set of variables. Up to 60 sets of values can be displayed in this chart.

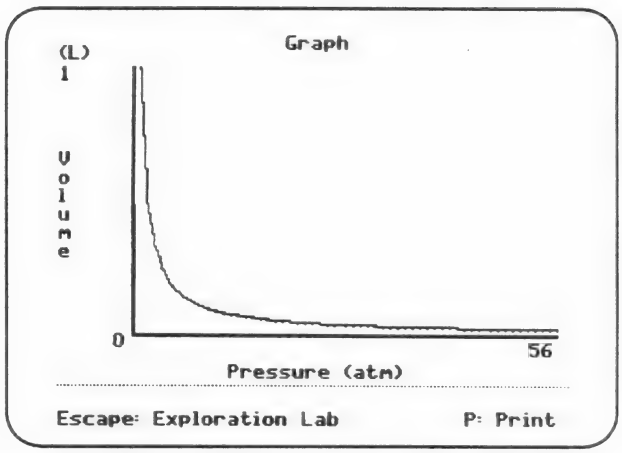
When you change the form of equation for the same law, the data will continue to be displayed. However, when you choose a new set of initial values (Boyle's, Charles', or Gay-Lussac's Laws), or change the law being demonstrated, the chart will be cleared and a new set of data will be collected and displayed. This chart can be printed by pressing the P Key.



Teacher Hint: If you do not have a printer connected, encourage students to record on their worksheets (see page 28) variable conditions and the results of each trial. Most students will find these records helpful for later analysis and discussion. Although printouts look nicer, students will probably profit more from recording the variable selections and results of each trial themselves. Maintaining their own records encourages them to think about the selections they have made and the events they have observed.

Graph

By selecting Graph, you can view the data that has been collected and (as displayed in the chart) plotted as a line graph. Up to 60 points can be plotted using the current set of variables and initial values. This graph can be printed by pressing the P Key.

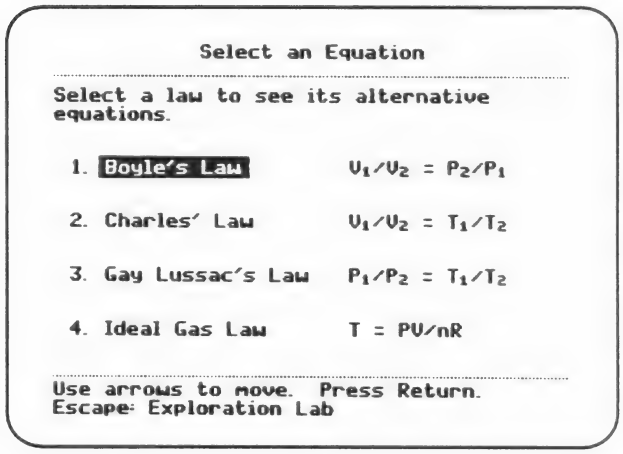


Equation

To explore the relationship between a new set of variables, select Equation from the menu bar. Choosing Equation takes you to a screen displaying each of the four laws and the equation form currently selected. To select one of these laws, use the arrow keys and press Return. Available equations are also listed in Informational Bulletin #2 (see page 25).

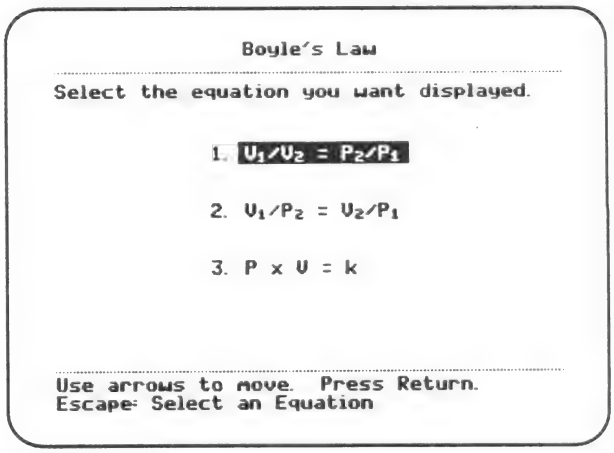
With each law that you choose, the appropriate set of variables is automatically displayed in the menu bar and the gauges will display values of one liter at standard temperature and pressure (STP).

Note: When you escape from this screen, the highlighted option is automatically selected.


Select an Equation
Select a law to see its alternative equations.
1. Boyle's Law V1/V2 = P2/P1
2. Charles' Law V1/V2 = T1/T2
3. Gay Lussac's Law P1/P2 = T1/T2
4. Ideal Gas Law T = PV/nR
Use arrows to move. Press Return.
Escape: Exploration Lab

The equations for each of these laws can be expressed in several forms. Choosing one of the four laws takes you to a screen where you can select one of the equation forms listed.

Note: If you escape from this screen, the highlighted option is automatically selected.


Boyle's Law
Select the equation you want displayed.
1. V1/V2 = P2/P1
2. V1/P2 = V2/P1
3. P x V = k
Use arrows to move. Press Return.
Escape: Select an Equation

Display

You can display the selected equation on the Explore Lab screen by pressing the D Key. When you press the D Key, the equation is displayed in two forms:

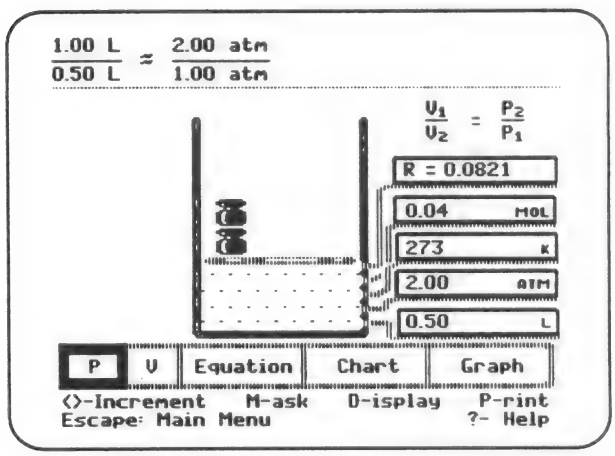
- the selected equation; and
- that same equation but with values that you can change by modifying the variables in the gauges.

Pressing the D Key a second time removes the displayed equation.

The displayed equation will show the initial values you have chosen and the incremented current value of the manipulated variables.

Note: Due to space limitations, the values displayed in the equation and the gauges may not match.

Also, due to computer round-off errors, it is not always possible to display equality in the equation displayed at the top of the screen. As a result, the equation is shown with an approximation sign instead of an equal sign.



THE PROGRAM AT A GLANCE (continued)

Mask

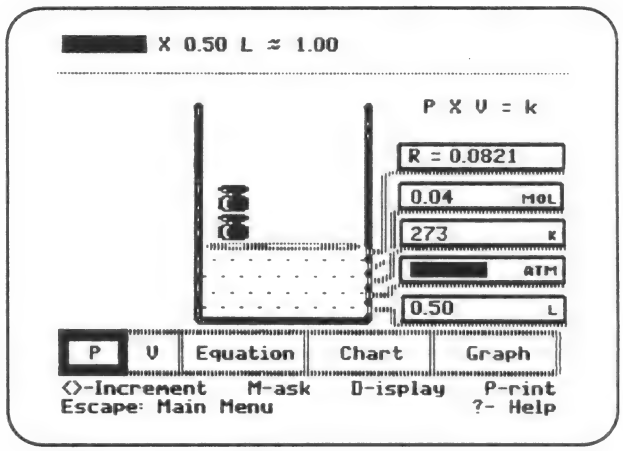
You can place a temporary mask over one element in a displayed equation to enable students to predict changing values.

Position the mask in equations such as P x V = *k* by moving the cursor to the desired variable symbol on the menu bar and pressing the M Key. A mask appears in that variable's position in both the equation and in the gauge. Remove the mask by pressing the M Key a second time.

In equations that display two values for the same variable (such as V_1 and V_2), the mask is always displayed over the second value.

In Ideal Gas Law equations, you can place a Mask over the dependent variable by moving the cursor to Equation and pressing the M Key.

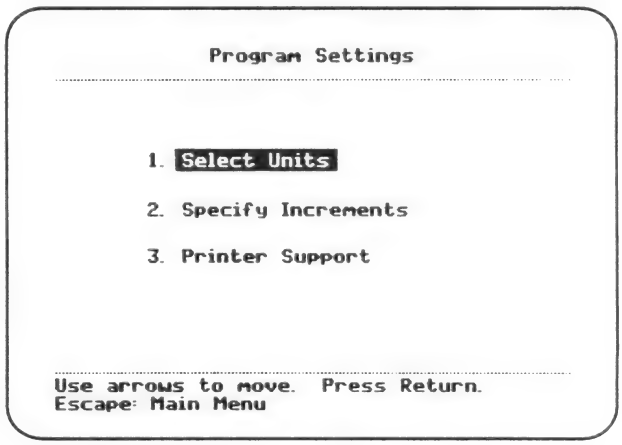
Note: You can position a mask before or after displaying an equation, and values can be changed while a mask is displayed. Entering a new starting value will erase the mask.



Program Settings

Select Option 2, Program Settings, from the main menu to view or edit default units, increments, and printer settings. Changes you make to these settings will remain in effect until you return to Program Settings to change them again.

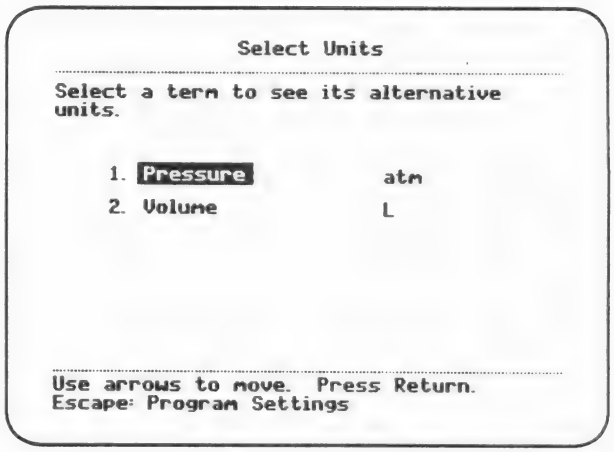
Choosing Program Settings takes you to a screen that presents you with three options: Select Units, Specify Increments, and Printer Support.



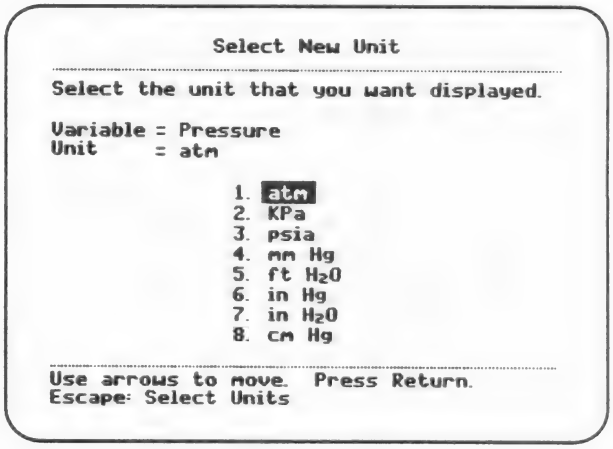
Select Units

For example, choosing Select Units takes you to a screen from which you can view or select the units for the variables pressure and volume.

Note: The value of the universal gas constant, R, is dependent on the units used. R is equal to 0.082 when one mole of a gas is at STP. R equals 62.4 if 760 mm of mercury is used for the pressure instead of one atmosphere.


Select Units
Select a term to see its alternative units.
1. Pressure atm
2. Volume L
Use arrows to move. Press Return.
Escape: Program Settings

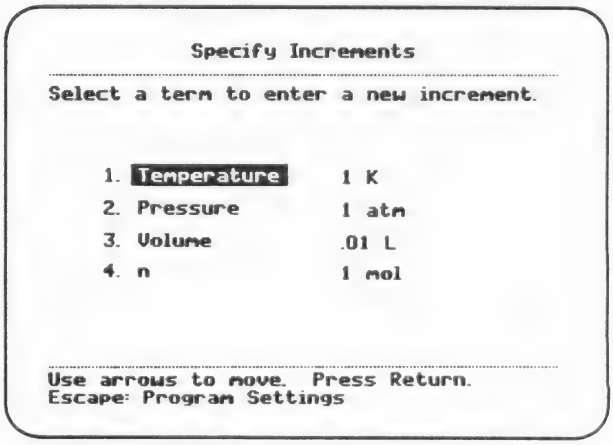
Each of the two Select Units options takes you to another screen where you can view the unit options for the variable you selected. Use the arrow keys to select a unit and press Return. The unit you select will be displayed in **Exploration Lab** until you return to Program Settings to change it.



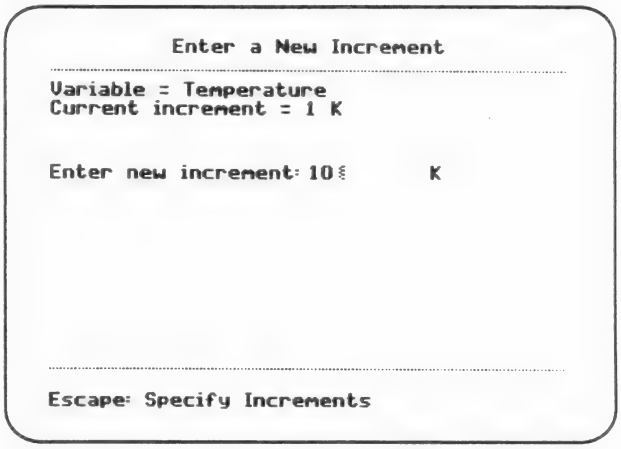
Specify Increments

The values selected for each variable in **Exploration Lab** can be increased or decreased by pressing the > and < Keys.

To specify the amount by which the values for each variable increase or decrease, select Option 2, Specify Increments, from the Program Settings menu and press Return. Then choose the desired variable to change.


Specify Increments
Select a term to enter a new increment.
1. Temperature 1 K
2. Pressure 1 atm
3. Volume .01 L
4. n 1 mol
Use arrows to move. Press Return.
Escape: Program Settings

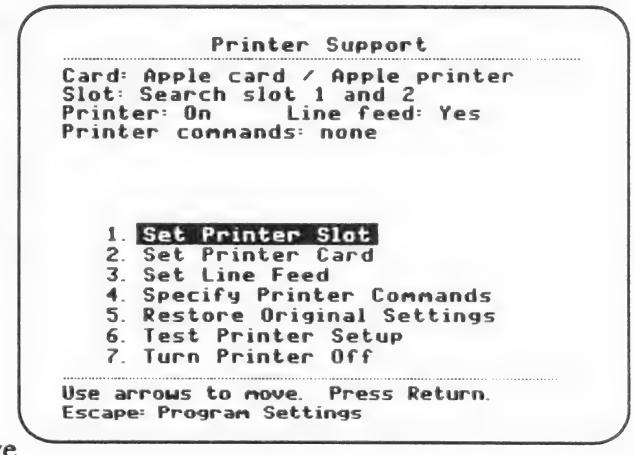
When you choose Option 1, Temperature, you will see a screen like the one shown here. The screen identifies the variable chosen and the increment currently selected. If the increment shown is acceptable, press Escape to return to the menu. Alternatively, type the increment you want used for this variable and press Return.



Printer Support

Exploring Gas Laws is initially set to work with an Apple //e computer with a standard printer card in either Slot 1 or 2. If you have this setup, you do not need to do anything further. If your printer uses a different setup or if you need to enter special printing commands, you must select the Printer Support option from the Program Settings menu. To connect an Apple //c or IIGS computer, designate Slot 1 and use the printer port on the back of the computer.

Selecting the Printer Support option takes you to the Printer Support menu. The current printer setting are displayed at the top of the screen. These options enable you to set up your printer for use with ***Exploring Gas Laws.***


Printer Support
Card: Apple card / Apple printer
Slot: Search slot 1 and 2
Printer: On Line feed: Yes
Printer commands: none
1. Set Printer Slot
2. Set Printer Card
3. Set Line Feed
4. Specify Printer Commands
5. Restore Original Settings
6. Test Printer Setup
7. Turn Printer Off
Use arrows to move. Press Return.
Escape: Program Settings

Option 1, Set Printer Slot, enables you to specify the slot number containing the printer interface card. Unless set otherwise, the program will search Slots 1 and 2 for a recognizable printer interface card.

Option 2, Set Printer Card, allows you to select the type of printer and interface card that you have attached to your computer.

Option 3, Set Line Feed, allows you to specify a line feed after each carriage return.

Option 4, Specify Printer Commands, allows you to enter commands that enable certain types of printers to operate. This option also permits you to set special printing formats. These special commands are listed in the manufacturer's printer or interface card manual. *Do not set up your printer to use a proportional font. This setting will cause the student records to be formatted incorrectly.*

To enter special commands, type the exact characters required. When you are finished entering commands, type ^ (Shift-6) to end.

Option 5, Restore Original Settings, returns all printer settings to their original state. The original settings provide for a search of Slots 1 and 2 and do not use special commands.

All changes made to the Printer Support setting are saved on the disk when you leave the Printer Support menu and are permanent until you use the Printer Support option again to change the settings.

Option 6, Test Printer Setup, prints out all of the keyboard characters. If these characters are not printed correctly, you can check the setting on your printer, check whether your printer has been correctly connected, or consult your interface card manual for special commands.

Option 7, Turn Printer On/Off, places or removes the Print Command from appropriate screens and activates or de-activates the print function.

USE IN AN INSTRUCTIONAL SETTING

Exploring Gas Laws is designed to be used to investigate the behavior of an ideal gas as expressed in Boyle's Law, Charles's Law, Gay-Lussac's Law, and the Ideal Gas Law. **Exploration Lab** is primarily designed for demonstrations as an "electronic, interactive transparency." With this program, teachers can provide an environment in which students can discover and/or review the behavior of gases and gain both a qualitative and quantitative understanding of the predictable relationships these laws describe.

Exploration Lab places students in a setting where they are confronted by problems that require their active participation. The program provides a setting that focuses the students' attention on the essential aspects of these experiments. The students have great flexibility and control of the problems, selecting and using values for the essential variables.

Exploration Lab is a realistic, easy-to-use simulation that allows students to investigate the gas laws. As in all good simulations, it carefully avoids distracting variables that are irrelevant or unimportant for attaining stated instructional goals. All instructional materials are most powerful when they are used with other educational experiences, rather than when they are used in strict isolation. ***Exploring Gas Laws*** is specifically designed to support and complement actual hands-on laboratory experimentation.

Exploring Gas Laws encourages active student intellectual involvement in several ways: by providing an open and creative environment in which they can develop and apply problem-solving strategies, by emphasizing the development and use of appropriate science inquiry process skills, and by capitalizing on natural curiosity and encouraging its use while learning appropriate and accurate scientific content.

Beginning students can experiment with many different strategies, such as observing the graphic and data displays, to develop a "feeling" for the relationships among the variables. Students should carefully record variable settings and experimental results, analyze the collected data, and make predictions. More advanced students may use their observations and collected data to develop equations that express the relationships being studied. Displaying an equation during experiments can also help students learn the more formal aspects of these relationships.

Exploring Gas Laws can easily be used in your classroom for large-group demonstrations and for small-group or individualized instruction.

USE IN AN INSTRUCTIONAL SETTING (continued)

You can easily use ***Exploring Gas Laws*** to meet your specific instructional objectives. The teacher-student-computer interaction is always most effective (leading to achievement by the largest number of students) when your students are thinking throughout the lesson. The way you guide the inquiry process and student interaction is essential to high levels of student involvement and learning. To maintain a high level of student interaction during a demonstration, consider a lesson format that includes the processes suggested below.

1. Use questions to find out what the students already know about gases, phases of matter, etc., and any misconceptions that they may have. Provide students with background information necessary for them to be able to understand the basic concepts that are illustrated in this simulation. Some student questions may include the following:

   What is a gas? What is an ideal gas? What are the phases of matter? What is a phase change? What are the conditions necessary for a phase change? What are temperature, volume, pressure, and amount (n)? How are these variables measured? What are the units used to measure them? How are units converted? What is a variable? What is a controlled variable? What is an experimental variable?

2. Clearly state the instructional objectives and results that you expect all students to have achieved by the end of the lesson.

   Be specific. For example, "By the end of today's lesson, you will be able to correctly state Boyle's Law in your own words." The science-inquiry skills involved in planning and carrying out an investigation and evaluating results should also be included in your objectives. For example, "By the end of today's lesson, you will be able to predict a correct model for the relationship between volume and pressure based on events you have observed and data you have collected."

3. Through class discussion, involve the students in planning the processes and sequential steps for each investigation.

   Have students help you identify the following: problem, variables, process to be followed in selecting and changing variable conditions, results to be observed, data to be collected, methods of interpreting and summarizing the data, methods of making and testing predictions, and so on.

4. Provide the students with a summary of their planned investigation and Data Collection Worksheets.

   Have someone write the investigative procedure on the chalkboard as it is being discussed. Duplicate copies of the planned investigation for each student to refer to during the investigation. Supply sufficient Data Collection Worksheets for each student.

USE IN AN INSTRUCTIONAL SETTING (continued)

5. If the students are going to use the **Exploration Lab** program individually or in small groups, you may want to demonstrate the use of the program before they begin.

   - Demonstrate how to select one of the four laws (set of variables) that will be the subject of the current investigation in **Exploration Lab**.

   - Explain the meaning and use of variables and demonstrate how to select, increase, decrease, or enter variable conditions in **Exploration Lab**.

     Distribute copies of Informational Bulletin #1 (see page 24).

   - Demonstrate the Support and Action Options students will need to successfully complete an investigation.

     Distribute copies of Informational Bulletins #2 and #3 (see pages 25 and 26).

6. As the investigation proceeds, involve the class in selecting variables and the conditions to be entered into the computer.

   Allow the students to identify which variable should be manipulated and which value should be selected. Enter, or have a student enter, the general consensus of the class into the computer. Require students to record observations and to base responses on an analysis of their data.

7. Provide sufficient time for students to record data, make calculations, discuss and analyze observations, and ask questions. Pursue answers to relevant questions through further investigation and discussion.

   Allow time during the investigation for students to digest what is happening and to formulate and ask questions. Call upon the class to suggest a way to determine answers.

8. Simulations depend on questioning for the development of cognitive processes in the learner. Guide the investigation through questions that require students to record and interpret data.

   Some students may need their curiosity directed when first encountering open-ended, unguided simulations. Present your questions in the form of a problem. Your questions should require students to initiate processes, change the value of variables, and observe results before they can respond.

USE IN AN INSTRUCTIONAL SETTING (continued)

9. Guide students to graph collected data, make predictions based on their analyses, and check their predictions.

   Some students have difficulty interpreting columns of data. Encourage them to put their data in an appropriate graphic format.

10. Lead frequent discussions that encourage students to share and compare interpretations and to summarize the investigation at various points.

    Group discussion and group decision making is one way to involve an entire class. It provides a method of restating or reinforcing learning that has taken place and provides the teacher with feedback as to how well students really understand the concepts and principles involved.

11. As students become familiar with the concepts and processes, increase the level of challenge.

    For example, if it is evident that students have a "feel" for the principles stated in Boyle's Law, encourage them to derive an equation that will express that relationship. Having derived an equation, test their understanding by displaying the equation and using the Mask command to test their predictions.

12. At the conclusion of the demonstration, organize the students into small groups. Allow the groups ten minutes to discuss the investigations, the events they observed, and the conclusions that may be drawn.

    Circulate from group to group to facilitate the discussion and to ask questions leading to a correct interpretation of the observed events. At the end of ten minutes, invite a representative of each group to summarize the group's findings. Allow for a large-group discussion and summary.

13. Have each student write a report summarizing the investigation and its conclusion.

    You can evaluate whether individual students have met the stated objectives and check their understanding with unguided practice in the form of a written report.

THINKING SKILLS

Using MECC Science Products to Reinforce Core Thinking Skills

MECC science products have as their primary goal to provide an environment in which students can learn and reinforce the use of science inquiry or science process skills. This science inquiry process include observing, collecting or recording data, organizing data, analyzing data, forming hypotheses or predictions, constructing models, and testing models. The purpose of the scientific method is to provide an organized approach to solving problems.

Each step in the inquiry process is, of course, related to and supported by a web of core thinking skills. A good science observer also displays good focusing skills, information gathering skills, remembering skills, and so on. A good scientist is, therefore, skilled at both appropriate scientific techniques and appropriate thinking skills.

Even though they share some terminology, the science inquiry process specifically relates to what science is and what a scientist does. While the core thinking skills are life skills necessary for the well-being of everyone in every situation, one can have science inquiry skills and be a poor scientist because one has poor thinking skills. Alternatively, having good thinking skills alone does not make one a good scientist. Therefore, science inquiry skills and core thinking skills, although closely intertwined, really present the teacher with two quite different sets of teaching objectives.

While the primary goal of the MECC science products is to highlight and reinforce science inquiry skills, the rich environment each product presents is also well suited to fostering good thinking skills.

When teaching thinking skills with these science products, please keep in mind that although only one example of the use of a particular thinking skill is correlated to a particular part or use of a program, the same skills can be practiced on many levels and in many aspects of these programs.

Thinking Skills and *Exploring Gas Laws*

Everywhere you turn in education today you hear about the need for a new curriculum, a curriculum in which thinking skills are emphasized. Learning is a lifelong process, necessary for survival, and children must acquire the skills to cope with our ever-changing world. Thinking has been given many names: problem-solving, process skills, critical thinking, abstract thinking, cognitive processes, and metacognition.

No one doubts nor disagrees that children need to learn and apply thinking skills. Everyone involved in education wants what is taught to include student thinking. But how do educators sort through the myriad pieces of information they receive on thinking skills? There are such a wide variety of strategies and approaches to teaching thinking skills that it is easy to be confused about what is meant by thinking skills and how to best teach them.

MECC believes the role of the teacher is to be the driving force in determining the classroom environment for thinking. We believe that good teachers have always emphasized thinking skills in their classrooms and will continue to do so using a variety of strategies. Our committment is to provide teachers with materials that will help them do their job well: quality software that promotes the application of thinking skills. MECC products are designed for the integration of thinking skills into the curriculum.

Exploring Gas Laws is a product that emphasizes science process skills. Because ***Exploring Gas Laws*** is a discovery-learning simulation, this product capitalizes on the natural curiosity of students and encourages them to develop appropriate scientific process skills while learning appropriate basic scientific content. The process orientation of this package mirrors the real world of scientific investigation while presenting material that is firmly anchored in the elementary and junior high school science curriculum.

Exploring Gas Laws provides a rich environment for students to practice skills of quality thinkers. Research has shown that students become more skillful thinkers when they:

- have opportunities to become actively engaged in problem-solving;
- answer thoughtful questions;
- ask questions of their own;
- listen to others;
- take part in projects that require searching and interpreting information.

This section of the manual highlights ways in which teachers can also use ***Exploring Gas Laws*** to promote thinking skills with their students. It is based on the thinking skills framework, *Dimensions of Thinking*, published in 1988 by the Association of Supervision and Curriculum Development (ASCD). We chose to use this framework because it pulls together the research and models from a variety of sources and brings the theory to the classroom level, applying it to that environment. In the next few pages, examples of how the science process skills and ***Exploring Gas Laws*** relate to the ASCD core thinking skills framework are given.

We realize the importance of thinking skills in the curriculum and are confident that you will find ***Exploring Gas Laws*** of considerable value in your classroom as you foster your students' thinking skills.

A Framework for Thinking

The components used in thinking are referred to as *core thinking skills*. This framework defines those skills that appear in the repertoire of the model learner. Each skill selected is documented in research as important to learning or thinking, is teachable, and is valued by educators as important for students to learn.

The core skills of the ASCD* framework are listed and defined below, with examples of applications within the scientific inquiry process. The skills are not discrete or hierarchial. In fact, individual skills draw on other skills and can be used repeatedly in the thinking process. The selected examples are not exhaustive but highlight ways in which these thinking skills are used with ***Exploring Gas Laws***.

* ***Dimensions of Thinking,*** Association for Supervision and Curriculum Development (ASCD), 1988.

Definition of Core Thinking Skills Categories	Core Thinking Skills Components	*Exploring Gas Laws* Application
Focusing Skills allow students to attend to selected pieces of information and to ignore others. Focusing occurs when students sense a problem, an issue, or a lack of meaning.	**Focusing Skills** • Defining Problems • Setting Goals	The student's task is to discover how each of four variables influence the behavior of an ideal gas under controlled conditions.
Information Gathering Skills involve obtaining information and clarifying issues and meanings through inquiry.	**Information Gathering Skills** • Observing • Formulating Questions	As students manipulate variables, the graphic display of the gas-filled cylinder will be affected. Students may observe changes in the position of the plunger, width of the cylinder, number of weights, the data gauges, and the values displayed in an equation.
Remembering Skills are those activities or strategies that students consciously engage in to store and retrieve information from long-term memory. Activating prior knowledge falls under this category.	**Remembering Skills** • Encoding • Recalling	Students will be able to state each of the gas laws (General Gas Law, Charles' Law, Boyle's Law, or Gay-Lussac's Law) and use them to solve problems.

Definition of Core Thinking Skills Categories	Core Thinking Skills Components	*Exploring Gas Laws* Application
Organizing Skills are used to arrange information so it can be understood or presented more effectively.	**Organizing Skills** • Comparing • Classifying • Ordering • Representing	Students compare and contrast information to gain an understanding of the relationships among temperature, pressure, volume, and amount of gas in a container. Using the three support options, charts, graphs, and equations, students can represent their collected data.
Analyzing Skills are used to clarify existing information by examining parts and relationships. Through analysis, students identify and distinguish components, attributes, claims, assumptions, or reasoning.	**Analyzing Skills** • Identifying Attributes and Components • Identifying Relationships and Patterns • Identifying Main Ideas • Identifying Errors	Students gain an understanding of the gas laws by determining how each of the variables—temperature, pressure, volume, and amount — influence the behavior of an ideal gas under controlled conditions. Students should also develop an understanding of the relationship among the gas laws.
Generating Skills involve using the students' prior knowledge to add information beyond what is given. Connections between new ideas and prior knowledge are made as new information and ideas are recast into new structures.	**Generating Skills** • Inferring • Predicting • Elaborating	Students are encouraged to make predictions based on their analysis and to verify their predictions by demonstrating the behavior of a gas under a given set of conditions.
Integrating Skills involve putting together the relevant parts or aspects of a solution, understanding, principle, or composition and incorporating this integrated information into a new understanding.	**Integrating Skills** • Summarizing • Restructuring	More advanced students will use their observations and collected data to develop equations that will express the relationships being studied.
Evaluating Skills involve assessing the reasonableness and quality of ideas.	**Evaluating Skills** • Establishing Criteria • Verifying	In this simulation, evaluation is an on-going process. As students observe, formulate questions, and make predictions, the program provides feedback verifying their input through the actions that take place on the screen.

CLASSROOM ACTIVITIES

A Demonstration of the Non-Ideal Behavior of Gases

Most chemistry texts explain that ideal gases follow Boyle's Law, Charles' Law, and so on. If gases really were "ideal" or "perfect"—that is, if there were absolutely no attractive forces acting among the molecules—these laws would always be followed. However, "real" gases are not perfect and they don't always obey the gas laws.

If real gases had no attractive forces acting among them, they would not liquify at low temperatures. Since all gases can be liquified under the right conditions, there must be some kind of attraction among the molecules. The existence of these attractive forces can be demonstrated with a plastic syringe and a can of Freon gas. You can purchase a small can of Freon (example: Pocket Dust-Off) from any photographic supply store.

Force the plunger of a small, disposable plastic syringe all the way to the bottom. Place the orifice at the bottom of the syringe against the nozzle of the can of Freon. Inject enough Freon to push the plunger almost to the top of the syringe. Put a rubber stopper on your desk and place the orifice of the syringe against the top of it. Push down on the plunger so that the gas is about 90% compressed. When you do so, the gas will begin to liquify. If you continue to push down and then release the pressure slowly, the then–liquid Freon will be seen to boil away back into the gas phase. Note that Freon has been shown to be environmentally harmful.

You may want to perform this demonstration at each student workstation so that everyone will have a clear view of what happens. Follow the demonstration with a classroom discussion of the behavior of gases, critical temperatures, refrigerants, etc.

Safety Note: If the can of Freon is discharged while it is upside down, liquid Freon will be discharged. Liquid Freon will freeze your skin in a matter of seconds.

For a more detailed description of this and other demonstrations, see the article "It's the Real Thing" by Mike McMillan, referred to on page 33.

A Demonstration of Avogadro's Principle

Avogadro's Principle states that equal volumes of different gases at the same temperature and pressure have different weights. Most students accept this basic principle. However, it is not easily demonstrated.

This principle can be demonstrated with some party balloons and a can of Freon gas. Inflate one balloon with some air. With the can of Freon gas, inflate a second balloon to the same size as the first.

Safety Note: Do not inflate the balloon while holding the can upside down. If the can of Freon is discharged while it is upside down, liquid Freon will be discharged. Liquid Freon will freeze your skin in a matter of seconds.

Hold the two balloons out in front of you. Remind the students that you now have equal volumes of two different gases with the same temperature and pressure. Release the two balloons at the same time. The Freon-filled balloon will quickly fall to the floor (Freon-12 is four to five times as dense as air). Note that Freon has been shown to be environmentally harmful.

Have the students pass the Freon-filled balloon around the room. Follow the demonstration with a classroom discussion of the meaning of Avogadro's Principle.

For a more detailed description of this and other demonstrations, see the article "It's the Real Thing" by Mike McMillan, referred to on page 33.

Five Simple Demonstrations with Air

1. *Pouring "nothing" from a container*
   This principle can be demonstrated with a small aquarium and two containers (500- to 600-ml beakers or flasks). Begin by showing students an "empty" container and ask them what is inside. Most students will respond, "nothing," although, some will say "air."

   Fill one container with water and submerge and invert it in the water-filled aquarium. Invert the second container and submerge it in the aquarium. Students will note that the second container does not fill with water when it is submerged. Ask them why the water does not rush into the "empty" container (answer: because it is really filled with air).

   Move the air-filled container so that it is under the water-filled container. Slowly tilt the air-filled container so that the air pours upward into the water-filled container. Ask the students to describe what is happening.

CLASSROOM ACTIVITIES (continued)

2. *Weighing air*
   Have a student weigh an empty balloon and then inflate it and weigh it again. The same student should make both determinations on the same scale. The air-filled balloon will weigh more than the empty balloon.

3. *Air pressure demonstration*
   Place a piece of paper over a partially filled container of water. Place your hand over the piece of paper and quickly invert the container. When you remove your hand, the water will stay in the container. (Note: When the paper gets wet, the seal will be lost and the water will spill out.) Ask the students to describe what is happening.

4. *Temperature and volume demonstration*
   Place a balloon over the mouth of a flask and heat the flask over a hot plate. As the air in the flask is heated, it will expand and inflate the balloon. When the balloon is inflated, the process can be reversed by placing the apparatus in a refrigerator or freezer. Ask the students to describe what is happening.

   Alternatively, inflate a round balloon. Measure its circumference and determine its volume. Gently heat the balloon in the sun or under a lamp for 30 minutes and determine its volume. Place the balloon in a refrigerator or freezer for 30 minutes and determine its volume again.

5. *Temperature and pressure demonstration*
   Add 5 to 10 ml of water to an empty mimeograph fluid can. Remove the cover and heat the can on a hot plate. After the can has been heated, replace the cover tightly and allow it to cool. As the can cools, air pressure will crush the can. Ask the students to describe what is happening.

   Alternatively, add 5 to 10 ml of water to an empty soda can. Heat the can on a hot plate. When steam begins to appear, use a pliers or tongs to quickly invert the can (mouth down) into a tray of cool water. The can will collapse immediately. Ask the students to describe what is happening.

   Or, place a glass tube a short way through a rubber stopper. Place the stopper into a 500-ml flask. Invert the flask and clamp it to a ring stand so that the tube extends into a beaker of water. Gently warm the flask and watch the level of water in the tube. Cool the flask and watch the level of water in the tube.

Safety Note: All experiments and demonstrations involving the use of a heat source require that appropriate safety measures be observed.

For a more detailed description of these and other demonstrations, see these articles, "What's the Big Deal about an Empty Bottle?" by Arthur Dolan, "Element of the Week" by Elizabeth Horsch, and "A Gas of a Class" by Steve Isom and Charles Lail referred to on page 33.

Discussing the Model

Exploring Gas Laws is built around a dynamic, mathematical model. Every effort has been made to guarantee that the mathematical model simulates reality. You should not, however, expect that student-collected data from classroom investigations will be the same as that collected for ***Exploring Gas Laws***. The interactive graphic display of the cylinder and piston is, on the other hand, only intended to approximate the mathematical changes you initiate.

As with all models, the ***Exploring Gas Laws*** model is greatly simplified, compared to the complexities of the real set of events being modeled. Models are, in fact, deliberately simplified to provide a greater opportunity to study and understand systems that are ordinarily very complex sets of cause-and-effect relationships. An important and interesting follow-up activity for your students might be to identify as many qualities and limitations as possible and to discuss their impact on the reality of the model.

The gas laws describe the behavior of a hypothetical or ideal gas. There is a value in studying a model for an ideal gas because it provides an approximation of the behavior of most real gases at no more than a couple of atmospheres of pressure and at temperatures that range from about room temperature to no more than a couple of hundred degrees.

Several factors differentiate real gases from ideal gases. Some of those differences are listed below.

In any real gas:

- every molecule has a real volume;
- there are forces of interaction among atoms and molecules;
- molecules have different shapes that affect collision; and
- high temperatures ionize and decompose molecules, forming a plasma.

The Ideal Gas Law assumes that the gas molecules are uniform, abstract points that do not interact.

INFORMATIONAL BULLETIN #1:
Introducing *Exploring Gas Laws* Variables

Variables

Variables are found on the menu bar. There are four variables—temperature, pressure, volume, and amount—two or three of which are available at any one time. Select variables with the arrow keys and press Return. Select variable conditions from a pop-up window in the same manner. Values can be entered directly from the keyboard when the desired variable symbol is highlighted. Values can also be increase by using the Greater Than (>) or Less Than (<) Keys.

T Temperature:
The temperature can only be entered and displayed in Kelvin. (Temperature conversion formulas can be found in "Informational Bulletin #4," on page 27.)

P Pressure:
The pressure is entered and displayed using one of these units:

atm
KPa
lbs/in^2
mm Hg
cm Hg
ft H_2O
in H_2O
in Hg

V Volume:
The volume is entered and displayed using one of these units:

l
ml
cm^3
ft^3

(n) Amount:
The amount is entered and displayed in moles.

INFORMATIONAL BULLETIN #2:
Introducing *Exploring Gas Laws* Support Options

Support Options

Support options are located on the menu bar. There are three Support options: Equation, Chart, and Graph. Select Support options with the arrow keys and press Return. Support options will take you to another screen where you can perform functions related to your investigations.

Equation

Enables you to select which of four laws you want to investigate: Boyle's Law, Charles' Law, Gay-Lussac's Law, and the Ideal Gas Law. With each law that you choose, the appropriate set of variables will automatically be displayed in the menu bar of **Exploration Lab**. You can also select one of several forms of the equation for each law. Press the D Key to display an equation.

Boyle's Law	$V_1 / V_2 = P_2 / P_1$ $V_1 / P_2 = V_2 / P_1$ $P \times V = k$
Charles' Law	$V_1 / V_2 = T_1 / T_2$ $V_1 / T_1 = V_2 / T_2$ $V / T = k$
Gay-Lussac's Law:	$P_1 / P_2 = T_1 / T_2$ $P_1 / T_1 = P_2 / T_2$ $P / T = k$
Ideal Gas Law: (PV = nRT)	$T = PV / nR$ $P = nRT / V$ $V = nRT / P$ $n = PV / RT$

Chart

Displays the variable conditions of each trial that used the currently displayed set of variables. Data is displayed in chart form. Chart enables you to review and analyze the data you have collected and to make predictions about changes in future trials. Press the P Key to print the chart.

Graph

Displays the variable conditions of each trial that used the currently displayed set of variables. Data is displayed in line graph form. Graph enables you to review and analyze the data you have collected and to make predictions about changes in future trials. Press the P Key to print the graph.

INFORMATIONAL BULLETIN #3:
Introducing *Exploring Gas Laws* Action Options

Action Options

Action options are found below the menu bar. There are six Action options: Increment, Print, Mask, Display, Escape, and Help. Select Action options by pressing the appropriate key. Action options enable you to take some immediate action.

Increment — Press the > or < Keys to increase or decrease the value of the variable you have highlighted on the menu bar. The values of each variable will change by a pre-determined amount unless you change it. Increments can be viewed/edited from the Program Settings menu.

Print — The Print option enables you to print any screen on which the option is found. You may, for example, print the Exploration Lab screen.

Mask — The Mask option enables you to temporarily place a mask on one of the elements in a displayed equation. To display a mask, select the desired variable symbol and press the M Key. The mask is removed by pressing the M Key again.

Display — The Display option enables you to display an equation expressing the law that is currently being investigated. When you press the D Key, the equation will be displayed in two forms: a form that is static and a form with displayed values that are updated as you change variable conditions. Pressing the D Key again will remove the displayed equations.

Escape — The Escape option ends the current set of investigations in **Exploration Lab** and returns you to the main menu. Returning to the main menu will cause all collected data to be erased from memory. If you wish to keep a permanent record of your data, print or copy all your data using the Chart and Graph options before returning to the main menu.

INFORMATIONAL BULLETIN #4:
Introducing *Exploring Gas Laws* Reference Information

Temperature Values

All temperature values selected/entered in **Exploration Lab** use the Kelvin scale. To convert Fahrenheit and Celsius (Centigrade) to Kelvin, you may use the conversion formulas shown below.

$5/9\ (°F - 32) = °C$
$°C + 273.16 = K$
$(°F - 32) \times 5/9 + 273.16 = K$

Conversion Factors

When performing investigations in **Exploration Lab**, you can select and display a number of different units. Whatever units you select, the program will automatically calculate and display the appropriate values. For your information, however, the conversion factors for these units are listed below.

1 lb	=	453.59 g
1 atm	=	14.696 psia (pounds per square inch)
1 atm	=	760 mm Hg
1 atm	=	76 cm Hg
1 atm	=	29.921 in Hg
1 atm	=	406.79 in H_20
1 atm	=	33.90 ft H_20
1 atm	=	1.01325×10^5 Pa
1 atm	=	101.325 KPa
1 in	=	2.54 cm
1 in	=	25.4 mm
1 ft	=	12 in
1 ft	=	30.48 cm
1 ft	=	304.8 mm
1 ft^3	=	28.316847 liters
1 l	=	1000 ml
1 ft^3	=	28316.847 cm^3
1 ml	=	1 cm^3
1 ft^3	=	28316.847 ml

Significant Digits

The selected/calculated values displayed in the **Exploration Lab** gauges should be considered to be measured quantities. Each displayed value will be measured to at least two significant digits.

Examples: 0.01, 0.25, 1.50, 7.00, 9.99

EXPLORING GAS LAWS
DATA COLLECTION WORKSHEET

Name _____

Temperature	Pressure	Volume	Amount	R

TEXTBOOK CORRELATION

Exploring Gas Laws is designed to support and enhance chemistry lessons dealing with the development of the Ideal Gas Laws. It can be easily correlated to chapters in your textbook and even used throughout the year with chapters that address related topics. The following charts correlate this product with specific chapters and sections in four popular chemistry textbooks: *Chemistry* (Addison-Wesley); *Chemistry —A Modern Course* (Merrill); *Chemistry — Experiments and Principles* (D. C. Heath); and *Modern Chemistry* (Holt, Rinehart, and Winston).

Chemistry (Addison-Wesley, 1987)

Chapter	Section	Page(s)	Topic
1	1.2	3	Boyle's Law.
	1B	4	Robert Boyle.
6	6B	129-130	Joseph Gay-Lussac.
	6.6	126	The volume of a mole of gas.
9	9.1	197-198	Kinetic theory and the nature of gases.
	9.2	198-200	Kinetic energy and temperature.
	9.3	200-201	Pressure.
10	10.1	221-222	The effect of adding or removing gas.
	10.2	223	The effect of changing the size of the container.
	10.3	223-224	The effect of heating or cooling a gas.
	10.6	226-228	Boyle's Law for pressure/volume changes.
	10.7	228-230	Charles' Law for temperature/ volume changes.
	10.8	230-233	Gay-Lussac's Law for temperature/ pressure changes.
	10.10	234-236	The Ideal Gas Law.

Chemistry —A Modern Course (Merrill, 1987)

Chapter	Section	Page(s)	Topic
1	1.5	9-10	Kinetic energy.
7	7.1	116-118	Early atomic theory.
15	15.4	289-290	Kinetic energy and temperature.
	15.5	291-292	States of matter.
18	18.1	345-346	Kinetic theory of gases.
	18.2	346-347	Boyle's Law.
	18.3	347-348	Applying Boyle's Law.
	18.5	351-353	Charles' Law.
	18.6	352-354	Applying Charles' Law.
	18.10	358-360	Deviations of real gases.
19	19.1	365-366	Developing Avogadro's Principle.
	19.3	367-368	Ideal Gas Law.
	19.10	378	Gases and work.

TEXTBOOK CORRELATION (continued)

Modern Chemistry (Holt, Rinehart, and Winston, 1986).

Chapter	Section	Page(s)	Topic
10	10.1	219-220	Kinetic theory.
	10.2	219-220	Observed properties of gases.
	10.3	220-222	Kinetic theory description of a gas.
	10.5	224-225	Dependence of gas volume on temperature and pressure.
	10.6	225	Standard temperature and pressure.
	10.7	225-226	Variation of gas volume with pressure: Boyle's Law.
	10.8	226	Using Boyle's Law.
	10.9	227	Variation of gas volume with temperature.
	10.10	227-228	Kelvin temperature scale.
	10.11	228-229	Charles' Law.
	10.15	233-235	Behavior of real gases.
11	11.2	240-244	Avogadro's Principle.
	11.12	254-256	The gas constant.
	11.13	256-257	Real gas and the ideal gas.

Chemistry—Experiments and Principles (D. C. Heath, 1982)

Chapter	Section	Page(s)	Topic
1	1-4	9-12	Measurement of gases.
	1-6	15-16	Boyle's Law.
2	2-1	26-29	Boyle's Law.
	2-2	29-32	Reacting volumes of gases.
4	4-2	67-69	The volume occupied by one mole of a gas.
	4-3	69-71	Pressure/temperature regularity.
	4-4	71	Volume/temperature regularity.
	4-4	71-72	Kinetic energy/absolute zero.

TEXTBOOK CORRELATION (continued)

The following charts correlate this product with specific chapters and sections in three popular physics textbooks: *Conceptual Physics* (Addison-Wesley); *PSSC Physics* (Heath); and *Physics Principles and Problems* (Merrill).

Conceptual Physics (Addison-Wesley, 1987)

Chapter	Section	Page(s)	Topic
4	4.6	44-45	Applying pressure.
20	20.1	283-284	Atmosphere.
	20.2	285-286	Atmospheric pressure.
	20.3	287-288	The simple barometer.
	20.4	289-290	The Aneroid barometer.
	20.5	290-291	Boyle's Law.
21	21.1	300-302	Kinetic energy/absolute zero.
	21.5	304-306	Quantity of heat.
22	22.4	318-320	Expansion and compression of gases.

PSSC Physics (Heath, 1986)

Chapter	Section	Page(s)	Topic
9	9.1	169-173	The volume and temperature of a gas.
	9.2	173-176	The volume and pressure of a gas. Boyle's Law.
	9.3	176-178	The general Gas Law and Boltzmann's Constant.
	9.4	178-181	The dynamics of gases.
	9.5	181-183	The effect of the velocity distribution.
	9.6	183-184	Temperature and molecular kinetic theory; internal energy.
	9.9	188-189	Heat capacities at constant volume and at constant temperature; specific heat.

Physics Principles and Problems (Merrill, 1986)

Chapter	Section	Page(s)	Topic
2	2.6	28-29	PV inverse variation.
12	12.1	195-196	Kinetic theory.
	12.2	196-197	Thermal energy and temperature.
	12.4	197	Temperature scales.
	12.5	198-199	The Kelvin or Absolute scale.
	12.6	199-201	First law of thermodynamics.
13	13.1	217-218	Assumptions of the kinetic theory.
	13.2	218-219	Pressure.
	13.3	219-221	Boyle's Law.
	13.4	221-223	Charles' Law.
	13.5	223-225	The Combined Gas Law.
	13.6	225	Ideal Gas Law.
	13.7	226	Real gases.

CREDITS

Exploring Gas Laws was produced by a MECC development team that included Gene Breault, Hassan Kaganda, Patricia Korn, Kevin Neff, and Diane Portner.

MECC extends a special thanks to the following people for their assistance in developing this product.

Mr. John Cacich
Northeast Metro Technical Institute 916
White Bear Lake, Minnesota

Mr. Dennis Chretien
MECC Training Division
St. Paul, Minnesota

Dr. Vivian Johnson
MECC/University of Minnesota Center
St. Paul, Minnesota

Mr. Donald Lindberg
St. Paul, Minnesota

Ms. Patricia R. Rustad
Shoreview, Minnesota

TO THE READER:

MECC has made every effort to ensure the instructional and technical quality of this courseware package. Your comments—as user or reviewer—are valued and will be included in any future revisions of the product. Please address comments to:

MECC Courseware Development
3490 Lexington Avenue North
St. Paul, MN 55126

REFERENCES

Clariana, Roy B. Computer Simulations of Laboratory Experiences. *The Journal of Computers in Mathematics and Science Teaching*, 14-19, Winter 1988/89.

Dolan, Arthur W. What's the Big Deal about an Empty Bottle? *The Science Teacher*, 50-51, October 1987.

Ganiel, Uri, and Idar, Joshua. Student Misconceptions in Science — How Can Computers Help? *The Journal of Computers in Mathematics and Science Teaching*, 14-19, Spring 1985.

Horsch, Elizabeth, *et al.* Element of the Week. *The Science Teacher*, 34-36, November 1987.

Isom, Steve, and Lail, Charles. A Gas of a Class. *The Science Teacher*, 45-47, March 1989.

McMillan, Mike. It's the Real Thing. *MSTA Journal*, 8, Vol. 33, No. 2, Spring/Summer 1986.

Roberts, Nancy, and Barclay, Tim. Teaching Model Building to High School Students: Theory and Reality. *The Journal of Computers in Mathematics and Science Teaching*, 13-24, Fall 1988.

Shaw, Edward, L., *et. al.* A Lesson Plan for Incorporating Microcomputer Simulations into the Classroom. *The Journal of Computers in Mathematics and Science Teaching*, 9-11, Summer 1984.

MECC SERVICES

Since its inception in 1973, MECC has remained committed to serving education by listening and responding to the diverse and changing needs of students and educators. MECC promotes effective learning by developing high-quality, curriculum-based software in all major subject areas and by making them affordable through a variety of purchase plans. Approximately one-third of the nation's school districts have joined MECC through Direct License memberships, permitting them to duplicate MECC software products on site. MECC products are also available through authorized dealers nationwide or can be ordered directly from the MECC catalog. In addition to software products, MECC offers instructional management, emerging technology products, teacher training and development, and conferences. An academic research partnership, the MECC/University of Minnesota Center for the Study of Educational Technology, conducts a variety of studies on the impact of technology on education. MECC respects the challenges faced by modern educators and pledges to remain on the cutting edge of technology.

- ***MECC Educational Computing Catalog***
  A catalog containing descriptions of instructional computing courseware as well as training and planning materials is published annually and distributed at no charge. To request a catalog, write or call MECC Customer Services.

- ***MECC Etc. Catalog***
  A catalog featuring "Emerging Technologies in the Classroom," such as laser videodisc players and LCD computer projection systems. Published twice a year and distributed at no charge. To request a catalog, write or call MECC Customer Services.

- **MECC Memberships**
  Educational institutions may become MECC Members, which qualifies them to obtain MECC courseware and training at specially reduced prices. To learn more about MECC Memberships, write or call MECC Marketing.

- **Training Programs**
  MECC conducts educational computing workshops for educators throughout the United States. For information on workshop schedules or to arrange a special training activity, write or call MECC Training Services.

- ***MECC Network* Newsletter**
  MECC publishes a quarterly newsletter during the school year that focuses on MECC activities, services, and products. To be added to the mailing list, simply write or call to indicate your interest.

- **Help Line**
  If you have any problems using MECC software:
  1) make note of the *name* and *version number* of the product;
  2) note the *brand* and *model* of the equipment involved, as well as the type of *printer card* used if the problem concerns a printer;
  3) write or call the Help Line to describe the problem.

For information on all the above items, use the MECC General Information telephone number: 612/481-3500.

MECC
3490 Lexington Avenue North
St. Paul, MN 55126